Building Java Programs

Chapter 5
Lecture 5-1: `while` Loops, Fencepost Loops, and Sentinel Loops

reading: 4.1, 5.1

self-check: Ch. 4 #2; Ch. 5 # 1-10

exercises: Ch. 4 #2, 4, 5, 8; Ch. 5 # 1-2

A deceptive problem...

- Write a method `printNumbers` that prints each number from 1 to a given maximum, separated by commas.

  For example, the call:

  ```
  printNumbers(5)
  ```

  should print:

  ```
  1, 2, 3, 4, 5
  ```

Flawed solutions

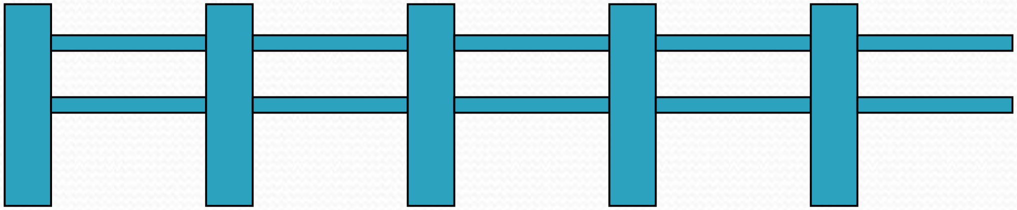
-
  ```
  public static void printNumbers(int max) {
      for (int i = 1; i <= max; i++) {
          System.out.print(i + ", ");
      }
      System.out.println();   // to end the line of output
  }
  ```
  - Output from `printNumbers(5)`: `1, 2, 3, 4, 5,`

-
  ```
  public static void printNumbers(int max) {
      for (int i = 1; i <= max; i++) {
          System.out.print(", " + i);
      }
      System.out.println();   // to end the line of output
  }
  ```
  - Output from `printNumbers(5)`: `, 1, 2, 3, 4, 5`

Fence post analogy

- We print *n* numbers but need only *n* - 1 commas.
- Similar to building a fence with wires separated by posts:
  - If we use a flawed algorithm that repeatedly places a post + wire, the last post will have an extra dangling wire.

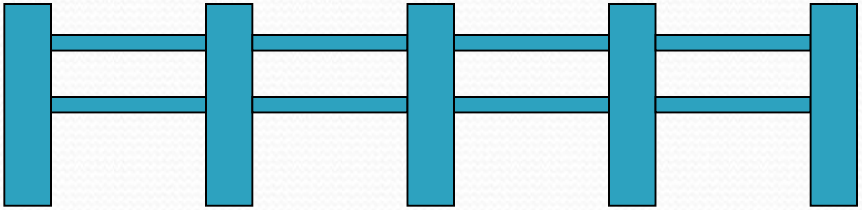
```
for (length of fence) {
    place a post.
    place some wire.
}
```



Fencepost loop

- Add a statement outside the loop to place the initial "post."
  - Also called a *fencepost loop* or a "loop-and-a-half" solution.

```
place a post.
for (length of fence - 1) {
    place some wire.
    place a post.
}
```



Fencepost method solution

```
public static void printNumbers(int max) {
    System.out.print(1);
    for (int i = 2; i <= max; i++) {
        System.out.print(", " + i);
    }
    System.out.println();       // to end the line
}
```

- Alternate solution: Either first or last "post" can be taken out:

```
public static void printNumbers(int max) {
    for (int i = 1; i <= max - 1; i++) {
        System.out.print(i + ", ");
    }
    System.out.println(max);  // to end the line
}
```

Fencepost question

- Modify your method `printNumbers` into a new method `printPrimes` that prints all *prime* numbers up to a max.
  - Example: `printPrimes(50)` prints

    ```
    2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47
    ```

  - If the maximum is less than 2, print no output.

- To help you, write a method `countFactors` which returns the number of factors of a given integer.
  - `countFactors(20)` returns `6` due to factors 1, 2, 4, 5, 10, 20.

Fencepost answer

```
// Prints all prime numbers up to the given max.
public static void printPrimes(int max) {
    if (max >= 2) {
        System.out.print("2");
        for (int i = 3; i <= max; i++) {
            if (countFactors(i) == 2) {
                System.out.print(", " + i);
            }
        }
        System.out.println();
    }
}

// Returns how many factors the given number has.
public static int countFactors(int number) {
    int count = 0;
    for (int i = 1; i <= number; i++) {
        if (number % i == 0) {
            count++;   // i is a factor of number
        }
    }
    return count;
}
```

`while` loops

reading: 5.1

self-check: 1 - 10

exercises: 1 - 2

videos: Ch. 5 #4

Categories of loops

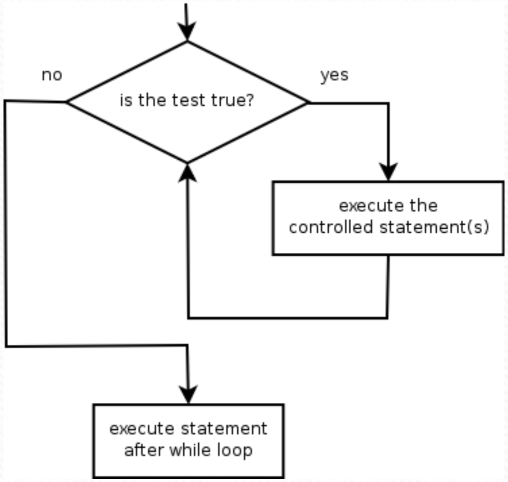
- **definite loop**: Executes a known number of times.
  - The `for` loops we have seen are definite loops.
    - Print "hello" 10 times.
    - Find all the prime numbers up to an integer *n*.
    - Print each odd number between 5 and 127.

- **indefinite loop**: One where the number of times its body repeats is not known in advance.
    - Prompt the user until they type a non-negative number.
    - Print random numbers until a prime number is printed.
    - Repeat until the user has types "q" to quit.

The `while` loop

- **`while` loop**: Repeatedly executes its body as long as a logical test is true.

```
while (test) {
    statement(s);
}
```


no
yes
is the test true?
execute the controlled statement(s)
execute statement after while loop

- Example:

```
int num = 1;                            // initialization
while (num <= 200) {                    // test
    System.out.print(num + " ");
    num = num * 2;                      // update
}

// output:  1 2 4 8 16 32 64 128
```

Example while loop

```
// finds the first factor of 91, other than 1
int n = 91;
int factor = 2;
while (n % factor != 0) {
    factor++;
}
System.out.println("First factor is " + factor);
// output:  First factor is 7
```

- while is better than for because we don't know how many times we will need to increment to find the factor.

Sentinel values

- **sentinel**: A value that signals the end of user input.
  - **sentinel loop**: Repeats until a sentinel value is seen.

- Example: Write a program that prompts the user for numbers until the user types 0, then outputs their sum.
  - (In this case, 0 is the sentinel value.)

```
Enter a number (0 to quit): 10
Enter a number (0 to quit): 20
Enter a number (0 to quit): 30
Enter a number (0 to quit): 0
The sum is 60
```

Flawed sentinel solution

- What's wrong with this solution?

```
Scanner console = new Scanner(System.in);
int sum = 0;
int number = 1;   // "dummy value", anything but 0

while (number != 0) {
    System.out.print("Enter a number (0 to quit): ");
    number = console.nextInt();
    sum = sum + number;
}

System.out.println("The total is " + sum);
```

Changing the sentinel value

- Modify your program to use a sentinel value of -1.
  - Example log of execution:

```
Enter a number (-1 to quit): 15
Enter a number (-1 to quit): 25
Enter a number (-1 to quit): 10
Enter a number (-1 to quit): 30
Enter a number (-1 to quit): -1
The total is 80
```

Changing the sentinel value

- To see the problem, change the sentinel's value to -1:

```
Scanner console = new Scanner(System.in);
int sum = 0;
int number = 1;  // "dummy value", anything but -1

while (number != -1) {
    System.out.print("Enter a number (-1 to quit): ");
    number = console.nextInt();
    sum = sum + number;
}

System.out.println("The total is " + sum);
```

- Now the solution produces the wrong output. Why?

```
The total was 79
```

The problem with our code

- Our code uses a pattern like this:

```
sum = 0.
while (input is not the sentinel) {
    prompt for input; read input.
    add input to the sum.
}
```

- On the last pass, the sentinel -1 is added to the sum:

```
    prompt for input; read input (-1).
    add input (-1) to the sum.
```

- This is a fencepost problem.
  - Must read *N* numbers, but only sum the first *N*-1 of them.

A fencepost solution

```
sum = 0.
prompt for input; read input.            // place a "post"

while (input is not the sentinel) {
    add input to the sum.                // place a "wire"
    prompt for input; read input.        // place a "post"
}
```

- Sentinel loops often utilize a fencepost "loop-and-a-half" style solution by pulling some code out of the loop.

Correct code

```
Scanner console = new Scanner(System.in);
int sum = 0;

// pull one prompt/read ("post") out of the loop
System.out.print("Enter a number (-1 to quit): ");
int number = console.nextInt();

while (number != -1) {
    sum = sum + number;     // moved to top of loop
    System.out.print("Enter a number (-1 to quit): ");
    number = console.nextInt();
}

System.out.println("The total is " + sum);
```

Sentinel as a constant

```java
public static final int SENTINEL = -1;
...
Scanner console = new Scanner(System.in);
int sum = 0;

// pull one prompt/read ("post") out of the loop
System.out.print("Enter a number (" + SENTINEL +
                 " to quit): ");
int number = console.nextInt();

while (number != SENTINEL) {
    sum = sum + number;     // moved to top of loop
    System.out.print("Enter a number (" + SENTINEL +
                     " to quit): ");
    number = console.nextInt();
}

System.out.println("The total is " + sum);
```